GUIDELINES FOR OBTAINING 100-YEAR FLOOD ELEVATIONS IN APPROXIMATE ZONE A OR UNMAPPED AREAS

A. Introduction

The items discussed in this document are intended to describe the minimum requirements needed in order to construct a reasonably reliable hydraulic model. The model is for determination of the approximate Base Flood Elevation (BFE) associated with a 100-year flood event on a limited reach of floodplain. This determination is needed to obtain a permit within a Zone A. Also discussed, is items necessary for submittal in order for the Montana Department of Natural Resources and Conservation (DNRC) to review a floodplain permit for development within Zone A's or unmapped flood zones. In the remainder of this document, the use of Zone A also implies an unmapped area.

The information contained here are guidelines and are not all encompassing. The State of Montana Floodplain Program recognizes that many situations are unique and will require analyses not covered in this document. If a site is unique and can pose distinct problems, it is very important that the landowner, surveyor, engineer, and floodplain administrator meet on the site. If the floodplain administrator will ask for DNRC review, an engineer within the appropriate DNRC regional office should also be present at the meeting. This initial visit by all parties concerned will help insure that work is not wasted on analysis found insufficient to meet the requirements for issuance of the permit.

A-1. Types of Floodplain Development

There are several types of development within the Zone A that require floodplain permits. These include but are not limited to single-family residential, commercial buildings, subdivision, channelization, irrigation structures, roads, bridges, levees, and other fills.

A single-family residence, of concern, is any built or manufactured home placed in the Zone A. A permit submitted for this type of structure is either to show the home above the BFE or to determine the elevation for which the home must be elevated.

A permit submitted for a commercial building is to show the building above the BFE, or to determine the elevation for which the building must be either elevated to or floodproofed to.

For the purposes of floodplain management, a subdivision is any multiple residence or commercial building development. As part of the subdivision, if any home, business, elevated road, fill, or any other development occurs within Zone A, a floodplain permit is required.

The State of Montana does not allow for the BFE to be increased in excess of 0.5 feet when construction is completed within the Zone A. Therefore, any channelization, irrigation structures, roads, bridges, levees, and other fills need to be permitted. You are encouraged to allow for even less than a 0.5 feet increase if a structure or road will be affected upstream of the development being permitted.

It needs to be emphasized that a levee must be certified before any development protected by the levee is removed from the Zone A. Constructing a levee to meet this certification is expensive and requires periodic maintenance and inspections of the levee. Unless the levee is certified, there will be no flood insurance premium reduction obtained. Along the same line, any fill used to elevate homes or businesses must be constructed in accordance with Federal Emergency Management Agency (FEMA) guidelines.

A-2. Steps in BFE Development

Determination of the BFE requires first that a 100-year discharge be estimated. There are several methods available to determine this discharge, but regardless of the method, the flow used will be an estimate. The accuracy and method needed to obtain this estimate is dependent on the sensitivity required by the activity being permitted. For example, the 100-year flow needed to determine the first floor elevation of a home would require more accuracy than the 100-year flow needed to ensure that a fill would not raise the BFE by more than 0.5 feet.

In order to model the 100-year flow, cross-sections will need to be surveyed and in some cases a topographic map prepared. For most cases, cross-sections of the stream will be sufficient, but in the case of a subdivision, a topographic map along with cross-sections will be required.

Once the hydrology and cross-sections are completed, a hydraulic analysis is required. Depending on the type of development and necessary analysis, this hydraulic analysis can be completed using either the normal depth method or a standard step backwater methodology.

In the case of subdivisions, once the hydraulic analysis is completed, a topographic base map showing the flood boundaries should be developed. If the flood boundaries change significantly from what is shown on the previous Zone A, a conditional letter of map revision (CLOMR) should be submitted.

If the purpose of the BFE development is for a single residence or business, a temporary benchmark should be established near the area of construction. If the purpose of BFE development is to show that the BFE is not increased by more than 0.5 feet, a testament to this fact should be stated by the engineer as part of the permit.

If the development is planned in an area that exceeds either 3 feet per second velocity or 3 feet of depth, a floodway zone, for any development, should be established using standard step backwater methodology. The floodplain and floodways should be mapped. No rise of the BFE whatsoever is allowed if the development is within the floodway.

B. Hydrology

If available, 100-year flood discharges can be obtained from previous work by Federal, State, or local agencies. If the area of concern is near a highway crossing, the Montana Department of Transportation (MDOT) may have computed a 100-year flow estimate. This information may be obtained from your county floodplain administrator or direct from MDOT. If other development has occurred recently in the same area, the county floodplain administrator may have 100-year flow estimates near your area of concern.

Before using a previous 100-year flow estimate, it is important to determine that conditions haven't changed significantly, or the methodology used is not inappropriate for the type of development and specific need that is being permitted. It should be explained in the permit application, why a 100-year flow estimate previously approved was not used.

It needs to be emphasized that this section is not intended to limit ingenuity on the part of the hydrologist, but it is also important to realize that much more documentation will need to be submitted, with the permit, if methods used go beyond these guidelines.

If a flow estimate needs to be computed, methods available include use of gage data, USGS regression equations, localized regression equations, gage data adjusted by USGS regression equations, or rainfall-runoff models.

B-1. Gage Data

Very seldom will gage data be available for the area of concern. First, the gage must be on the same stream as being analyzed. Second, the drainage area associated with the gage site must be within plus or minus 50% of the drainage area for which the analysis is being completed. If neither of these conditions are met, USGS regression equations are preferred.

The 100-year discharge can be found at USGS gage locations in "Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998," USGS, Water-Resources Investigations Report 03-4308. If a 100-year estimate is needed that is based on gage data beyond 1998, it may be found on the USGS Montana District Web page.

Often, the area being studied is not at or immediately near the gage site. If this is the case, the gage data will need to be adjusted using USGS regression equations. These procedures are explained in Section B-4.

B-2. USGS Regression Equations

Presented in the USGS Water-Resources Investigations Report 03-4308 are methods for determining flood-frequency data at ungaged sites. Use of the USGS regression equations, in this report, is the preferred method to use for ungaged streams. The State of

Montana is divided into eight regions, with each region having flood characteristics reasonably homogeneous. The eight regions are shown in Figure 1. For each region, there are three different equations that can be used to obtain 100-year flow estimates. The first method uses basin and climatic characteristics, the second uses active-channel width, and the third uses bankfull width.

Basin and climatic characteristics found to be significant in some or all of the eight regions include drainage area (A) in square miles, mean annual precipitation (P) in inches, mean basin elevation (E) in feet, percentage of the basin above 6,000 feet (E_{6000}), and percentage of basin covered by forest (F). These values, other than P, can be obtained from suitable-scale USGS quadrangle maps.

Basin and climatic characteristics can be considered causative factors of flooding, whereas active-channel width or bankfull width are resultant effects of flooding. Previous studies conducted by Chuck Parrett of the USGS have shown that regression equations based on either active-channel width or bankfull width are comparable in reliability to regression equations based on basin and climatic characteristics. In fact, regardless of average standard error of prediction (SEP), 100-year flood estimates using either channel width method may be more reliable than those using basin and climatic characteristics if the basin characteristics do not include variables that uniquely affect flooding at a particular site. On the other hand, channel width equations may not be reliable for unique geologic conditions such as bedrock channels or streams where the channel has recently changed as a result of large floods.

The active-channel width (W_{ac}), in feet, is defined on both sides by a break in the relatively step bank of the active channel to a more gently sloping surface beyond the channel. The break in slope normally coincides with the lower limit of permanent vegetation.

The bankfull width (W_{bf}), in feet, is defined on both sides as the place where the floodplain and the channel intersect and is usually distinguished by an abrupt change in slope from near vertical to horizontal.

Shown in Figure 2 is a typical cross-section with the locations of the active-channel and bankfull width shown. A sketch of a plan view of a typical alluvial stream indicating the best location for measuring either active-channel or bankfull width is shown in Figure 3. Widths should be measured at two or three locations and averaged before put into the regression equations. Typically, active-channel width is easier to define on perennial streams whereas bankfull width is easier to define on ephemeral streams.

It is recommended, that in all regions, the 100-year flow be estimated using a basin characteristics equation and one of the two channel width methods. The results of these two different equations should <u>not</u> be averaged giving the results of each methodology equal weight. In some cases, the results should be compared and one estimate chosen. It needs to be emphasized that SEP's shown are average. If the values input into the regression equations are near the extremes of values used to derive the equations, the SEP

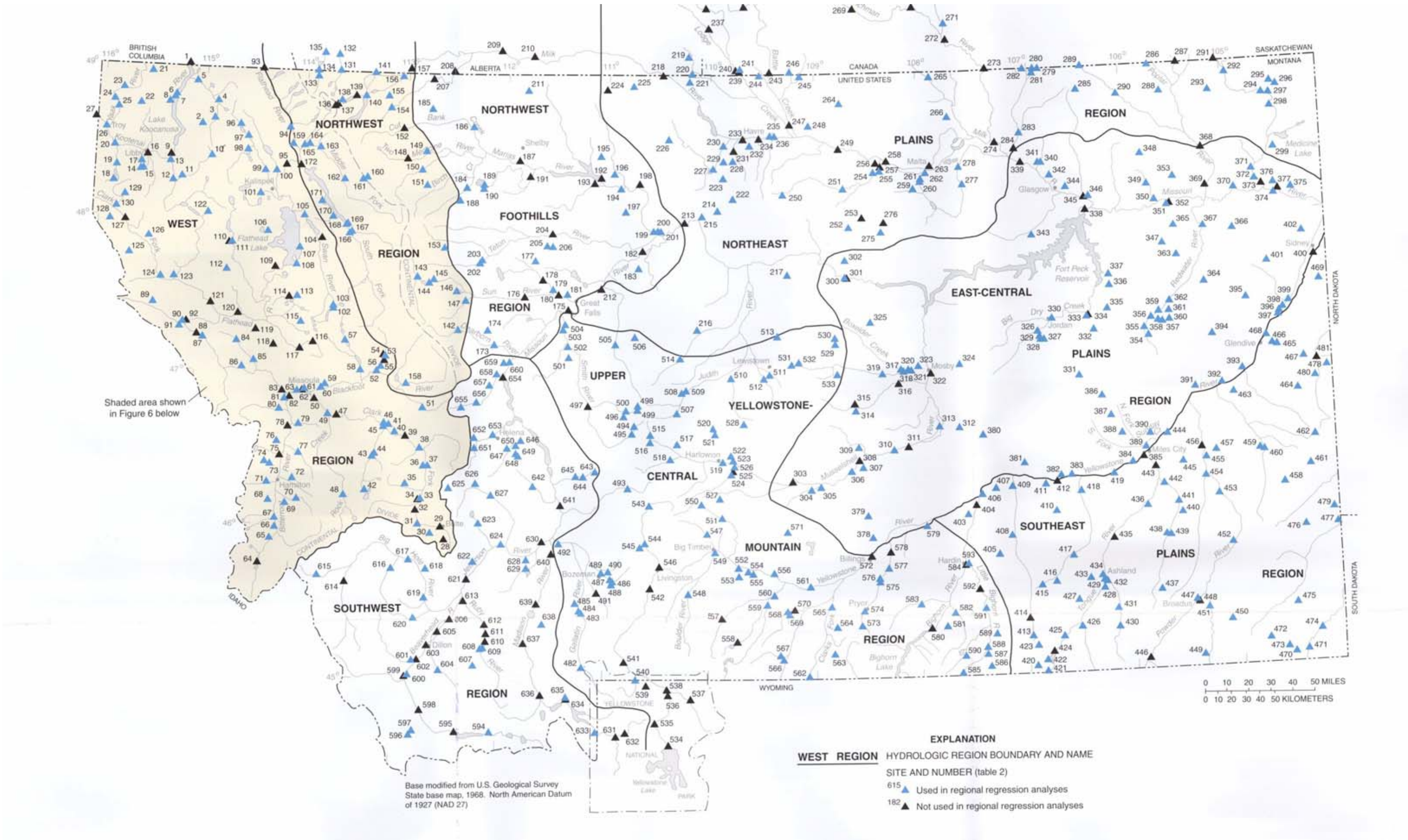

Figure 1 – Eight Hydrologic Regions Delineated by the USGS

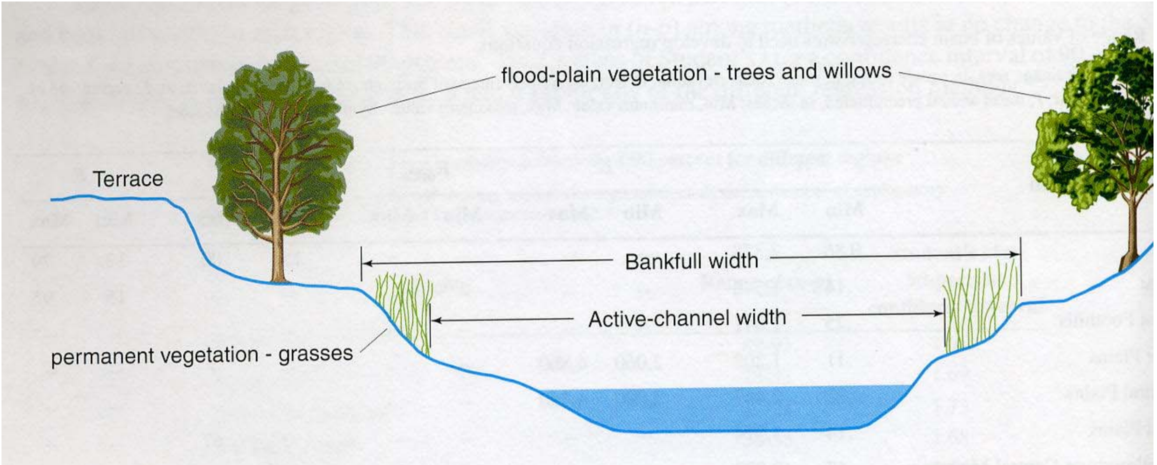

Figure 2 – Typical USGS Stream Cross-Section Showing Active Channel and Bankbull Widths

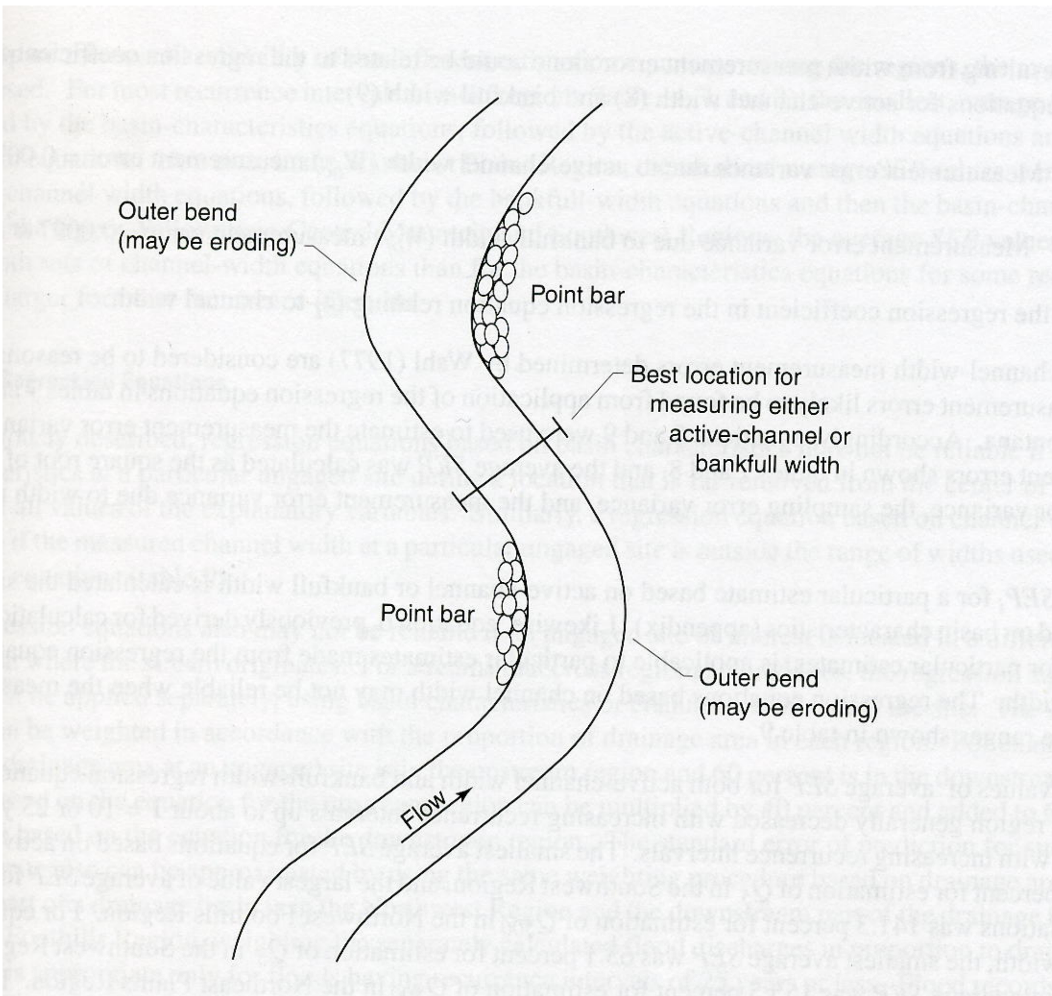

Figure 3 – Typical USGS Location for Measuring Channel Width

will be larger than the average SEP. The logic behind which estimate is chosen should be documented in the permit. If average of two different methods is desired, a weighted average, based on SEP, should be completed. A computer program that enables this weighted average to be determined is available on the Montana District USGS Web site.

Given below are the basin characteristic equations and channel width equations to use in each of the eight regions.

B-2a. West Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 1.

(1.) $Q_{100} = 18.7A^{0.812}P^{1.06}(F+1)^{-0.664}$ Average SEP is 58.5%

The Q_{100} using active channel width is given in Equation 2.

(2.) $Q_{100} = 9.57W_{ac}^{1.45}$ Average SEP is 69.6%

The Q_{100} using bankfull width is given in Equation 3.

(3.) $Q_{100} = 2.99W_{bf}^{1.66}$ Average SEP is 72.3%

The average annual precipitation (P) can be found in several sources including Water-Resources Investigations Report 03-4308.

B-2b. Northwest Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 4.

(4.) $Q_{100} = 56.4A^{0.71}P^{0.403}$ Average SEP is 40.2%

The Q_{100} using active channel width is given in Equation 5.

(5.) $Q_{100} = 60.0W_{ac}^{1.19}$ Average SEP is 86.7%

The Q_{100} using bankfull width is given in Equation 6.

(6.) $Q_{100} = 28.4W_{bf}^{1.29}$ Average SEP is 94.1%

The average annual precipitation (P) can be found in several sources including Water-Resources Investigations Report 03-4308.

B-2c. Northwest Foothills Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 7.

(7.) $Q_{100} = 462A^{0.537}$ Average SEP is 61.0%

The Q_{100} using active channel width is given in Equation 8.

(8.) $Q_{100} = 297W_{ac}^{0.919}$ Average SEP is 114%

The Q_{100} using bankfull width is given in Equation 9.

(9.) $Q_{100} = 124W_{bf}^{1.02}$ Average SEP is 122%

B-2d. Northeast Plains Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 10.

(10.) $Q_{100} = 1{,}190A^{0.462}(E/1000)^{-1.20}$ Average SEP is 101%

The Q_{100} using active channel width is given in Equation 11.

(11.) $Q_{100} = 116W_{ac}^{1.23}$ Average SEP is 115%

The Q_{100} using bankfull width is given in Equation 12.

(12.) $Q_{100} = 45.6W_{bf}^{1.30}$ Average SEP is 136%

B-2e. East-Central Plains Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 13.

(13.) $Q_{100} = 4{,}120A^{0.454}(E/1000)^{-1.84}$ Average SEP is 85.7%

The Q_{100} using active channel width is given in Equation 14.

(14.) $Q_{100} = 259W_{ac}^{1.08}$ Average SEP is 102%

The Q_{100} using bankfull width is given in Equation 15.

(15.) $Q_{100} = 88.3W_{bf}^{1.20}$ Average SEP is 104%

B-2f. Southeast-Plains Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 16.

(16.) $Q_{100} = 486A^{0.441}(F+1)^{-0.212}$ Average SEP is 91.6%

The Q_{100} using active channel width is given in Equation 17.

(17.) $Q_{100} = 136W_{ac}^{1.09}$ Average SEP is 74.3%

The Q_{100} using bankfull width is given in Equation 18.

(18.) $Q_{100} = 52.2W_{bf}^{1.18}$ Average SEP is 83.6%

B-2g. Upper Yellowstone-Central Mountain Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 19.

(19.) $Q_{100} = 181A^{0.702}(E_{6000}+1)^{-0.211}$ Average SEP is 56.8%

The Q_{100} using active channel width is given in Equation 20.

(20.) $Q_{100} = 115W_{ac}^{0.914}$ Average SEP is 88.7%

The Q_{100} using bankfull width is given in Equation 21.

(21.) $Q_{100} = 44.4W_{bf}^{1.09}$ Average SEP is 92.0%

B-2h. Southwest Region

The 100-year flood (Q_{100}), in cfs, using basin and climatic characteristics is given in Equation 22.

(22.) $Q_{100} = 351A^{0.682}(E_{6000}+1)^{-0.476}$ Average SEP is 80.3%

The Q_{100} using active channel width is given in Equation 23.

(23.) $Q_{100} = 41.8W_{ac}^{1.02}$ Average SEP is 91.3%

The Q_{100} using bankfull width is given in Equation 24.

(24.) $Q_{100} = 19.3W_{bf}^{1.15}$ Average SEP is 94.1%

B-3. Localized Regression Equations

There are times when five or more gaging stations exist that can be considered representative of the area being studied. The suitability of these gages for analysis is not measured only by proximity to the area being studied but also by similar hydrologic conditions. Often, a hydrologist will want to develop their own regression analysis based on 100-year flow estimates at these gaging stations. This analysis will either give the hydrologist more confidence in the results from the USGS equations or cause concern and further analysis. All localized regression analysis should be submitted with the permit with an explanation of why gages were selected and what was ascertained from the analysis.

Localized regression analysis is often completed using basin area as the independent variable and 100-year flow as the dependent variable. These variables are transformed into logarithm based 10 and simple linear regression conducted. An example of this analysis is shown in Figure 4. Use of more than one independent variable for regression analysis may also be considered. This type of analysis is beyond the scope of this document.

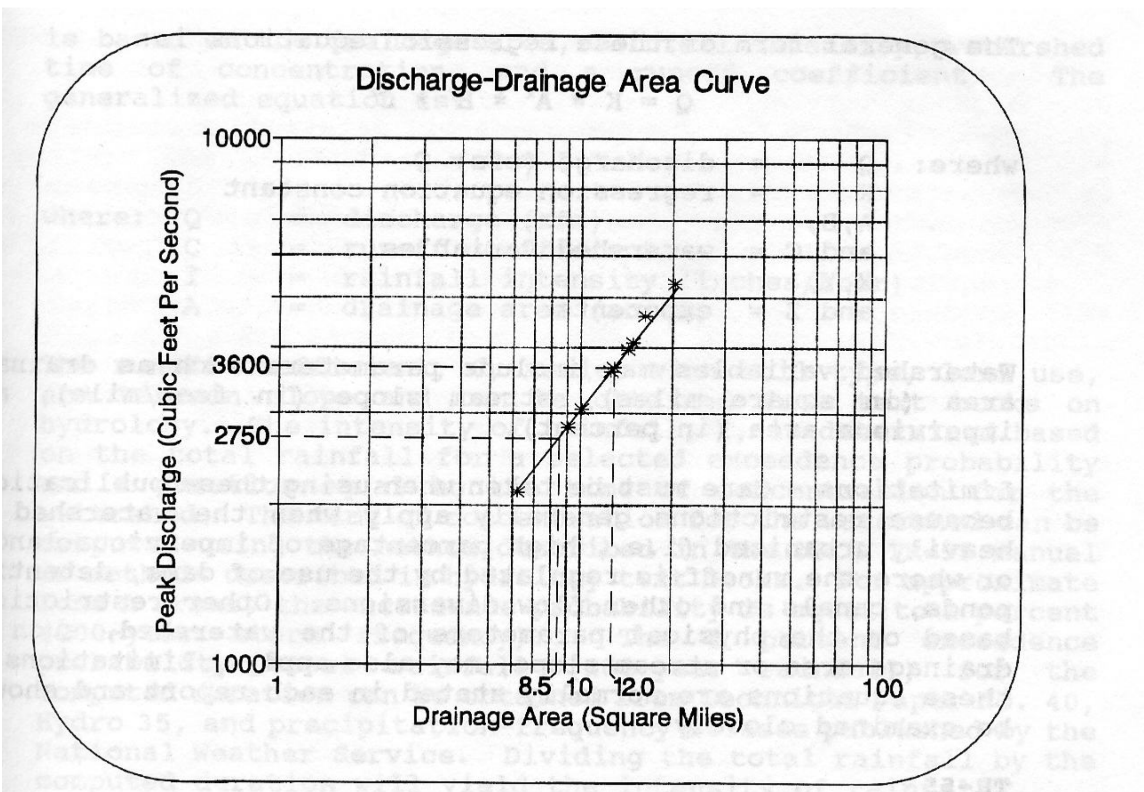

Figure 4 – Drainage Area vs. 100-Year Discharge Relationship

B-4. Gage Data Adjusted by USGS Equations

As explained in Section B-1, seldom is a gaging station located in the area being studied. If a gage is on the same stream and the drainage area associated with the gage within plus or minus fifty percent of the drainage area for the basin being studied, the 100-year flow from the gage can be used with adjustment. The adjustment comes from the exponents of the USGS regression equations. Only basin area, active channel width, or bankfull width should be used for this analysis. Use of this methodology can best be explained using the following two examples.

Example 1. A 100-year flow is needed on the Big Hole River. The area of concern has a drainage area of 2,000 square miles. Compute the 100-year flood.

> As shown in Figure 1, the Big Hole River is in the Southwest Region. There is a gage near Melrose called "Big Hole River near Melrose." The computed 100-year flow at this gage is 17,200 cfs. The basin area at this gage is 2,476 square miles. The exponent associated with drainage area for the Southwest Region is given in Equation 22. This exponent is 0.682. Therefore, the 100-year flow for the Big Hole River with a drainage area of 2,000 is $17{,}200(2{,}000/2{,}476)^{0.682}$ = 14,870 cfs.

Example 2. A 100-year flow is need for Ten Mile Creek near Helena. The area of concern has a drainage area of 20 square miles and an active channel width of 10 feet. Compute the 100-year flood.

> As shown in Figure 1, Ten Mile Creek is in the Southwest Region. There is a gage near Rimini with a basin area of 30.9 square miles and an active channel width of 16 feet. The computed 100-year flow at this gage is 1,240 cfs. The hydrologist feels that active channel width is the best indicator of 100-year flows in this area. Since the area of concern is within fifty percent of 30.9 square miles, the gage information can be used. The exponent associated with active channel width for the Southwest Region is given in Equation 23. This exponent is 1.02. Therefore, the 100-year flow for Ten Mile Creek with an active channel width of 10 feet is $1{,}240(10/16)^{1.02}$ = 768 cfs.

B-5. Rainfall-Runoff Models

Although the use of regional regression equations generally provides more reliable estimates of 100-year peak discharge than does the use of rainfall-runoff modeling, rainfall-runoff modeling is the only way to estimate 100-year flood conditions for certain watershed conditions. These conditions include basins that have seen significant urban development as a percentage within the basin, basins that have had major fires as a percentage within the basin, basins that contain significant flood storage, or basins with independent variables outside the range used to develop the USGS regression equations.

In Montana, the use of rainfall-runoff models can sometimes be justified for streams with small basin areas. The hydrologist needs to make a decision if the USGS regression equations may still be appropriate or whether a rainfall-runoff model would give better results. If the drainage area is less than ½ square mile, serious consideration should be given to using the rational method.

It is beyond the scope of these guidelines to list and discuss all methods available to complete rainfall-runoff models. If one of these methods is chosen, all assumptions and calibrated data should be supplied with the permit.

C. Cross-Section Development

For flood studies within Zone A's, the engineer or surveyor will most often need to obtain cross-sections using a field survey. If a normal depth methodology is used, only one cross-section will need to be surveyed, otherwise, the document prepared by DNRC called "Guidelines for Water Course Surveys in Undesignated or Zone A Flood Zones" should be used. This document can be found on the AMFM website.

D. Hydraulics

There are two hydraulic methods available for modeling BFE's along riverine flooding sources. The normal depth method is easy to apply but has limited application. In fact, for subdivisions, the normal depth method should not be used. The normal depth method is also inappropriate to show that development will cause less than 0.5 feet increase of the BFE. The other method available and most widely used to model BFE's is a step-backwater analysis. Both methods are discussed in this section.

D-1. Normal Depth Method

Normal depth is the depth expected for a stream when the flow is uniform, steady, one-dimensional, and is not affected by downstream obstructions or flow changes. For normal depth to be used, channel bottom slope, water-surface slope, and energy slope have to be very near parallel. Therefore, any downstream obstruction such as bridges, irrigation structures, channel chokes, or slope changes can make the method inappropriate to use. The distance downstream to be checked for these obstructions is shown in Table 1. The standard formula for determining normal depth at a cross-section is Manning's formula.

The standard Manning's equations is:

(25.) $Q = 1.486AR^{2/3}S^{1/2}/n$

Where:
- Q = Discharge (cfs)
- A = Cross-Section area (ft^2)
- R = Hydraulic radius (ft) = A/WP
- WP = Wetted perimeter (ft)
- S = Energy slope
- n = Manning's roughness coefficient

TABLE 1	
Channel Slope (ft/ft) (As determined by the average water course slope from USGS quadrangle topographic maps)	Minimum Distance "D" (ft) from the location of development to any obstruction that could create backwater
< 0.001	3000
0.001 – 0.0049	1500
0.005 – 0.01	500
> 0.01	100

The cross-section area refers to the area below the water-surface elevation, and the wetted perimeter refers to the length of the ground surface along the cross-section below the water-surface elevation. The channel bottom slope is used in lieu of the energy slope.

Manning's "n" values vary depending on the physical features of the stream channel and the channel overbanks. The results of normal depth calculations can differ significantly depending on the Manning's "n" values used. Therefore, documentation is needed in regard to how the value is chosen.

The BFE can be determined by hand but it can be a lengthy trial and error process. In this day and age, it makes more sense to use available computer programs such as the public domain software HEC-RAS or private vendor software such as Haestad's Flow Master.

If the structure within the Zone A is less than two feet above the BFE, serious consideration should be given to applying a step-backwater method.

D2. Step-Backwater Methods

Step-backwater computations are based on the principle of conservation of energy, which states that the energy at the upstream cross-section is equal to the energy at the downstream cross-section plus the losses between the two cross-sections. The losses considered in the step-backwater analysis are the friction loss and the transition loss.

Today, step-backwater methods are almost exclusively done using computer programs. One of the most popular programs is HEC-RAS. If your permit application is reviewed by DNRC, this is the program that personnel within DNRC are most familiar with. Use of models other than HECR-RAS will often require much more extensive written narratives along with oral presentations to DNRC.

If HEC-RAS is used, the Standard Table 1 should be generated and a hard copy submitted with the permit application. A disc with HEC-RAS input files or an e-mail with the input and output files as attachments should also be supplied.

Narratives for the following items should be submitted:

1. Assumed critical depths.
2. Flow through hydraulic structures (photographs also included).
3. Identify all artificial structures such as rip-raped banks.
4. Encroachments used.
5. Determination of starting water surface elevation.
6. Determination of Manning's n values.
7. Any other physical situations that cause water surfaces to rapidly increase or decrease.

If the purpose for the analysis is to show that development within the Zone A does not increase the BFE by greater than 0.5 feet, then two models will need to be submitted. The first model is before development and the second model for after development.

E. Conclusion

Permitting a development within an approximate Zone A area requires a detailed analysis that is often far more complex than the original analysis completed for mapping. In many cases, it is in essence, a detailed flood study in a small area within the Zone A. Therefore, if the DNRC is asked to review the permit, there are many submittals that will be requested. A checklist is given in Appendix A. In addition, a testament by the PE should be submitted that states that "in their professional judgment, the BFE or increase in water surface elevation submitted provides an accurate estimation."

Appendix A

Department of Natural Resources and Conservation
Limited Reach and Approximate A Zone Flood Studies

At the request of the community, the DNRC will review an engineering consultant's floodplain study for a particular property. DNRC engineers will review the study and either accept the consultant's findings or respond with a list of questions or issues. Consultants are encouraged to provide sufficient information for DNRC engineers to determine if the methodologies used and the results attained are reasonable and meet state requirements. Where professional judgment has been used to arrive at intermediate conclusions, please specifically state such in the report. It is recommended the consultant provide a cover letter and plan sheet addressed to the Community Floodplain Administrator summarizing the pertinent findings. The flood study report should be attached as a separate document. To provide guidance, the following checklist has been provided: Additional study information is available online at the AMFM website.

Section	Items	Required/Optional
Project	• Brief description of project and study objectives • Project Location –County, Township, Range, Section • Map or aerial photo of project location	RQD RQD RQD
Hydrology	• Summary of available gage sites and discharge estimations • Explanation of choice of discharge estimation method • Computations	RQD RQD RQD
Survey	• Benchmark description with datum (NGVD 1929, NAVD 1988 or reference) • Plan view showing watercourse, property bounds, cross section locations, proposed flood boundaries, benchmarks and any bridges, diversion dams, levees or other pertinent structures. • Photocopy of current FIRM at project location with panel number noted • Plots of cross sections looking downstream • Photos of channel, overbanks and any hydraulic structures • Establish temporary benchmark near development • Topographic data if flood boundaries are being drawn. Spot elevations or contours.	RQD RQD RQD OPT OPT OPT OPT
Hydraulics	• Discussion of choice of methodology, Normal Depth, Step Backwater (HEC-RAS), Other • Paper copies of input/output files and on disk • Discussions of model parameters including Manning's n values, starting water surface elevations, flow regime etc. • Discussion of any special concerns, bridges, levees, side channels, ineffective flow areas etc. • Discussion of model results, model warnings, assumed critical depths	RQD RQD RQD RQD RQD
Results	• Summary • BFE at project location • Maps of floodplain boundary (if required) • P.E. Stamp • Cover Letter to Floodplain Administrator	RQD RQD RQD